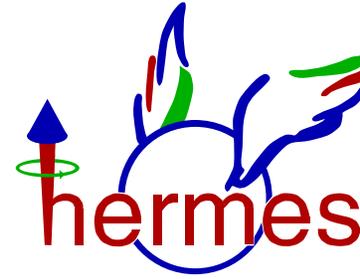


Azimuthal asymmetries in meson electroproduction at



Delia Hasch
on behalf of the HERMES collaboration

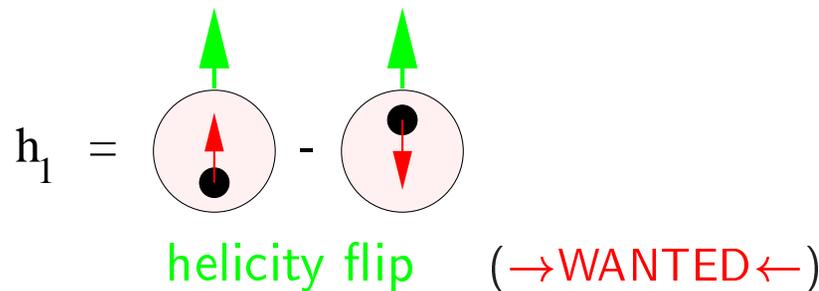
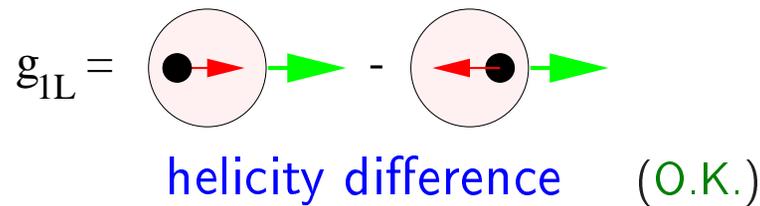


15th International Spin Physics Symposium
September 9-14, 2002; BNL, New York, US

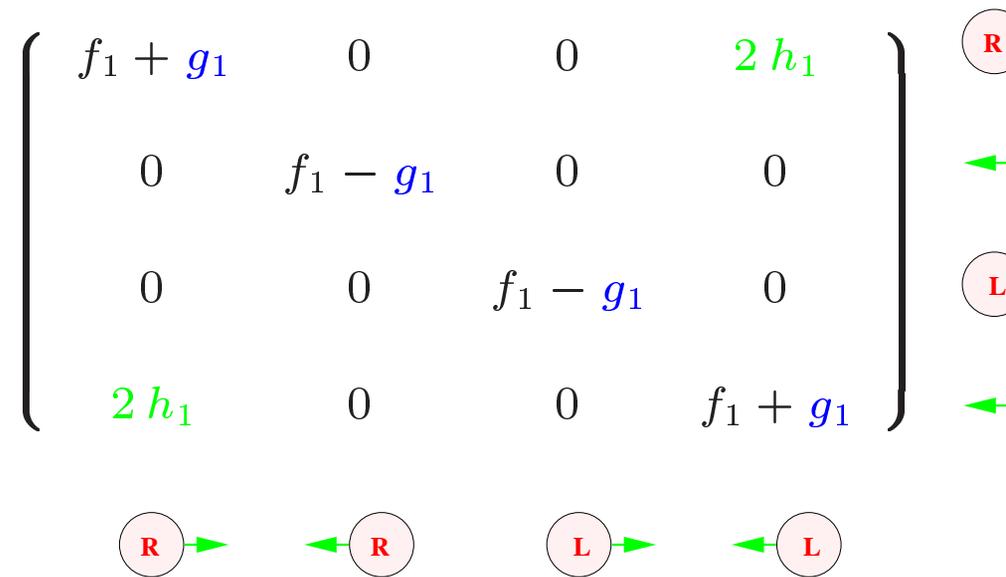
- introduction
- target-spin + beam-spin azimuthal asymmetries
- outlook



$$\Phi_{\text{corr}}^{\text{LO}}(x) = \frac{1}{2} [f_1(x) + S_L g_1(x) \gamma_5 + h_1(x) \gamma_5 \not{S}_T] \not{n}_+$$

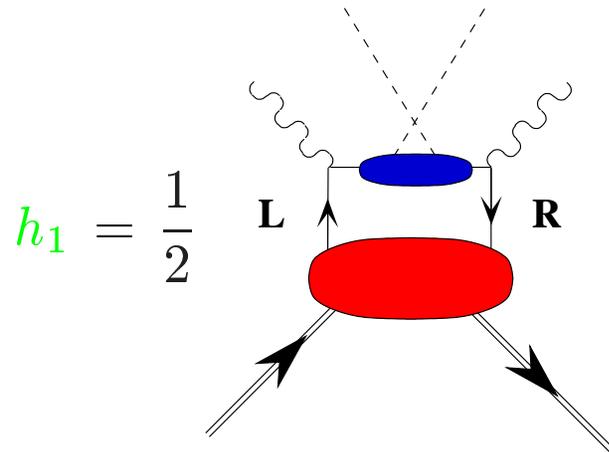


transverse spin state =
off-diagonal state in the helicity basis:



transversity

how to measure in SIDIS



→ **chiral odd**

→ observed only in combination with another chiral odd structure

→ interference fragmentation: $A_T (|p_{\perp} \rightarrow l + (\pi^+, \pi^-) + X)$

→ final state polarisation:

spin-1/2 (Λ) and spin-1 (ρ) fragmentation → see talks by H.C. Chiang,
U. Stösslein

→ Collins effect: $A_T (|p_{\perp} \rightarrow l + \pi + X)$

$$A_T = \langle \sin \phi \rangle_{UT} \propto h_1(x) \otimes H_1^{\perp}(z, k_T)$$

... azimuthal asymmetries

DIS+SIDIS cross section

[Mulders and Tangermann, NP B461 (1996) 197]

$$d\sigma = d\sigma_{UU}^0 + \frac{p_T}{Q} \cos \phi d\sigma_{UU}^1 + \lambda \frac{1}{Q} \sin \phi d\sigma_{LU}^2$$

f_1 ✓

$$+ S_L [\sin 2\phi d\sigma_{UL}^3 + \frac{1}{Q} \sin \phi d\sigma_{UL}^4] + \lambda S_L [d\sigma_{LL}^5 + \frac{1}{Q} \cos \phi d\sigma_{LL}^6]$$

h_{1L}^\perp ✓

g_{1L} ✓

$$+ S_T [\sin(\phi + \phi_S) d\sigma_{UT}^7 + \sin(3\phi - \phi_S) d\sigma_{UT}^8 + \frac{1}{Q} \sin(2\phi - \phi_S) d\sigma_{UT}^9]$$

h_1 ✓

h_{1T}^\perp ✓

$$+ \lambda S_T [\cos(\phi - \phi_S) d\sigma_{LT}^{10} + \frac{1}{Q} \cos(2\phi - \phi_S) d\sigma_{LT}^{11}]$$

g_{1T} ✓



transversity

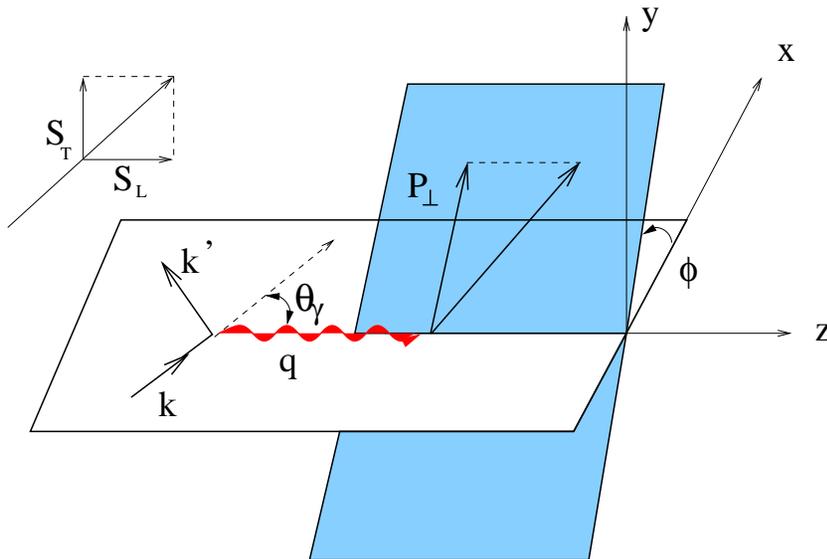
how to measure in SIDIS

$$\sigma^{eH \rightarrow ehX} = \sum_q f^{H \rightarrow q} \otimes \sigma^{eq \rightarrow eq} \otimes D^{q \rightarrow h}$$

\Downarrow
 chiral-odd DF

\Downarrow
 chiral-odd FF

\Rightarrow single-spin azimuthal asymmetries (SSA), where either the **beam** or **target** is polarised



P_{\perp} pion transverse momentum
 ϕ azimuthal angle of π around the virtual-photon direction

$$\begin{aligned}
 S_T &= |S| \sin \theta_{\gamma} \\
 &\simeq |S| \frac{2Mx}{Q} \sqrt{1-y} \sim 0.15
 \end{aligned}$$

target single-spin azimuthal asymmetry

$$A(\phi)_{UL} = \frac{1}{\langle P \rangle} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

$$\langle P_H \rangle = 0.86, \langle P_D \rangle = 0.84$$

$$Q^2 > 1 \text{ GeV}^2, W > 2 \text{ GeV}, y < 0.85$$

$$0.023 < x < 0.4$$

$$4.5 < E_{\pi^\pm} < 13.5 \text{ GeV (Cerenkov: 96,97)}$$

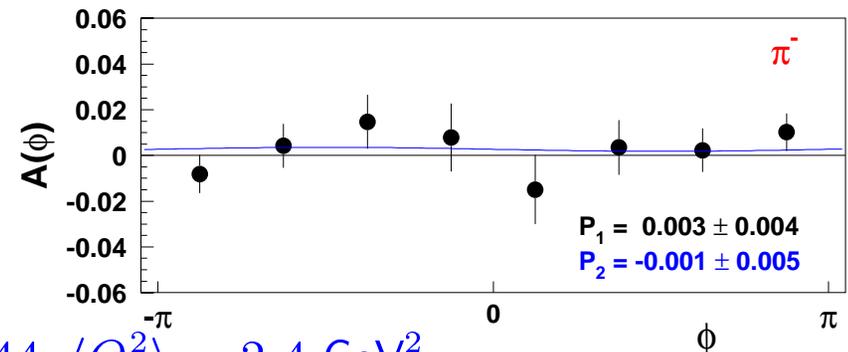
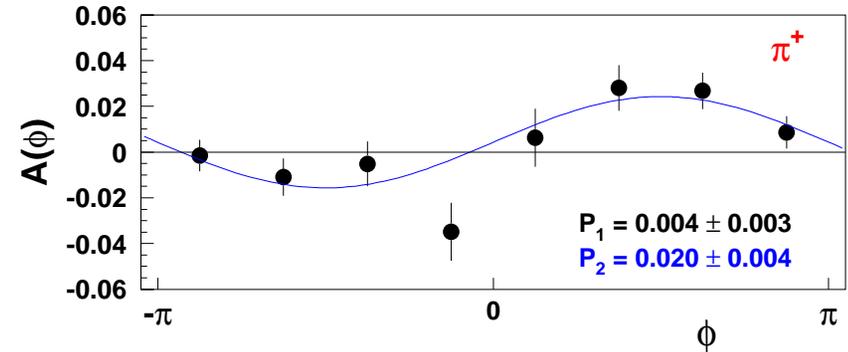
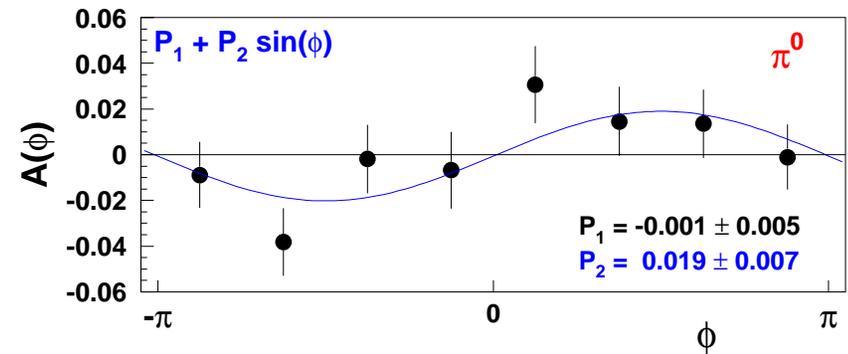
$$2.0 < E_{\pi^\pm, K^+} < 15.0 \text{ GeV (RICH: 98-00)}$$

$$\pi^0: E_\gamma > \text{GeV (neutral cluster)}$$

$$0.1 < m_{\gamma\gamma} < 0.17 \text{ GeV}$$

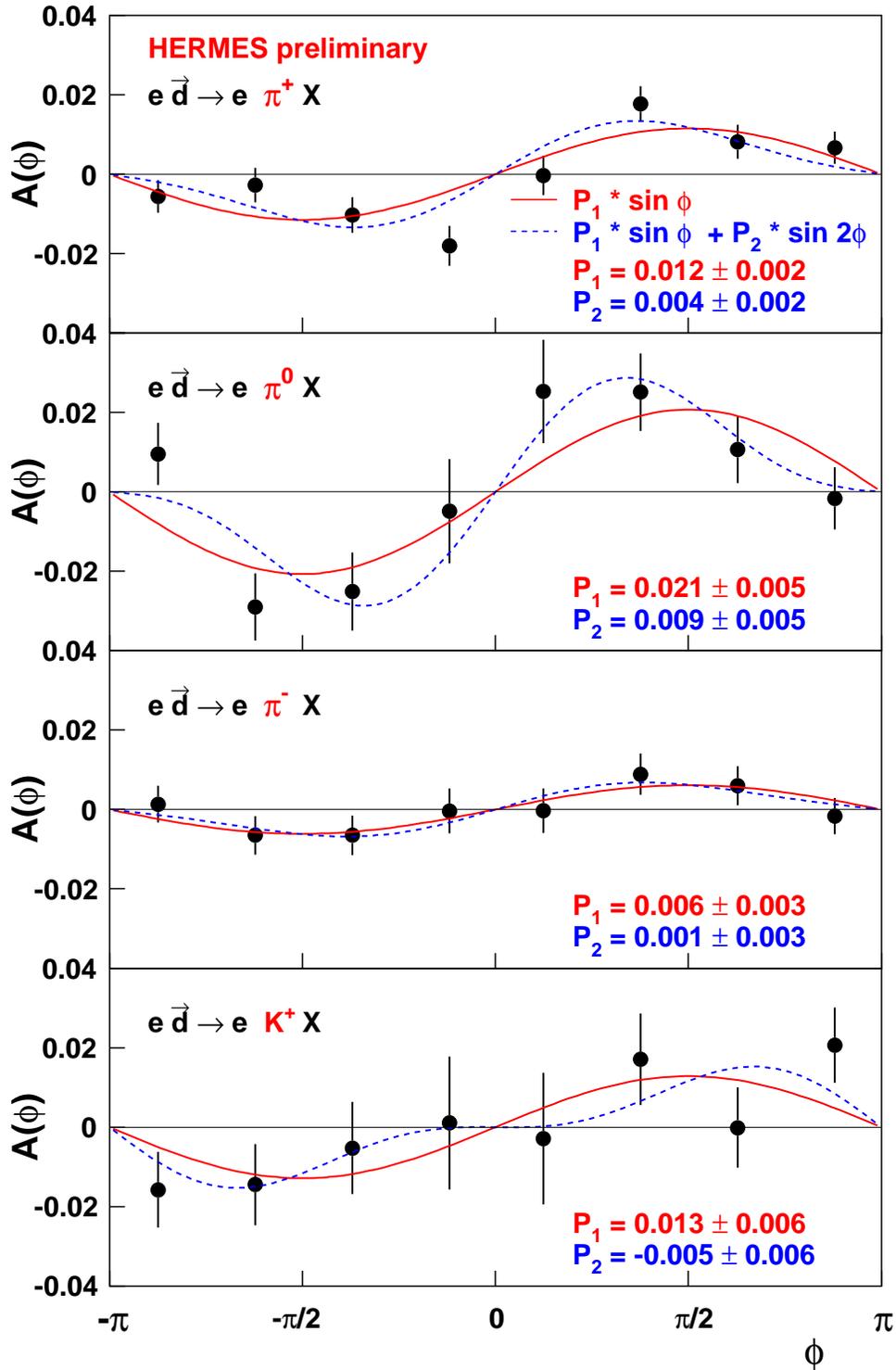
$$0.2 < z < 0.7, P_\perp > 0.05 \text{ GeV}$$

$$\langle x \rangle = 0.09, \langle y \rangle = 0.57, \langle z \rangle = 0.48, \langle P_\perp \rangle = 0.44, \langle Q^2 \rangle = 2.4 \text{ GeV}^2$$



target SSA

$$\langle x \rangle = 0.09, \langle y \rangle = 0.57, \langle z \rangle = 0.48, \langle P_{\perp} \rangle = 0.44, \langle Q^2 \rangle = 2.4 \text{ GeV}^2$$



azimuthally weighted asymmetries

analysing powers for target longitudinal polarisation:

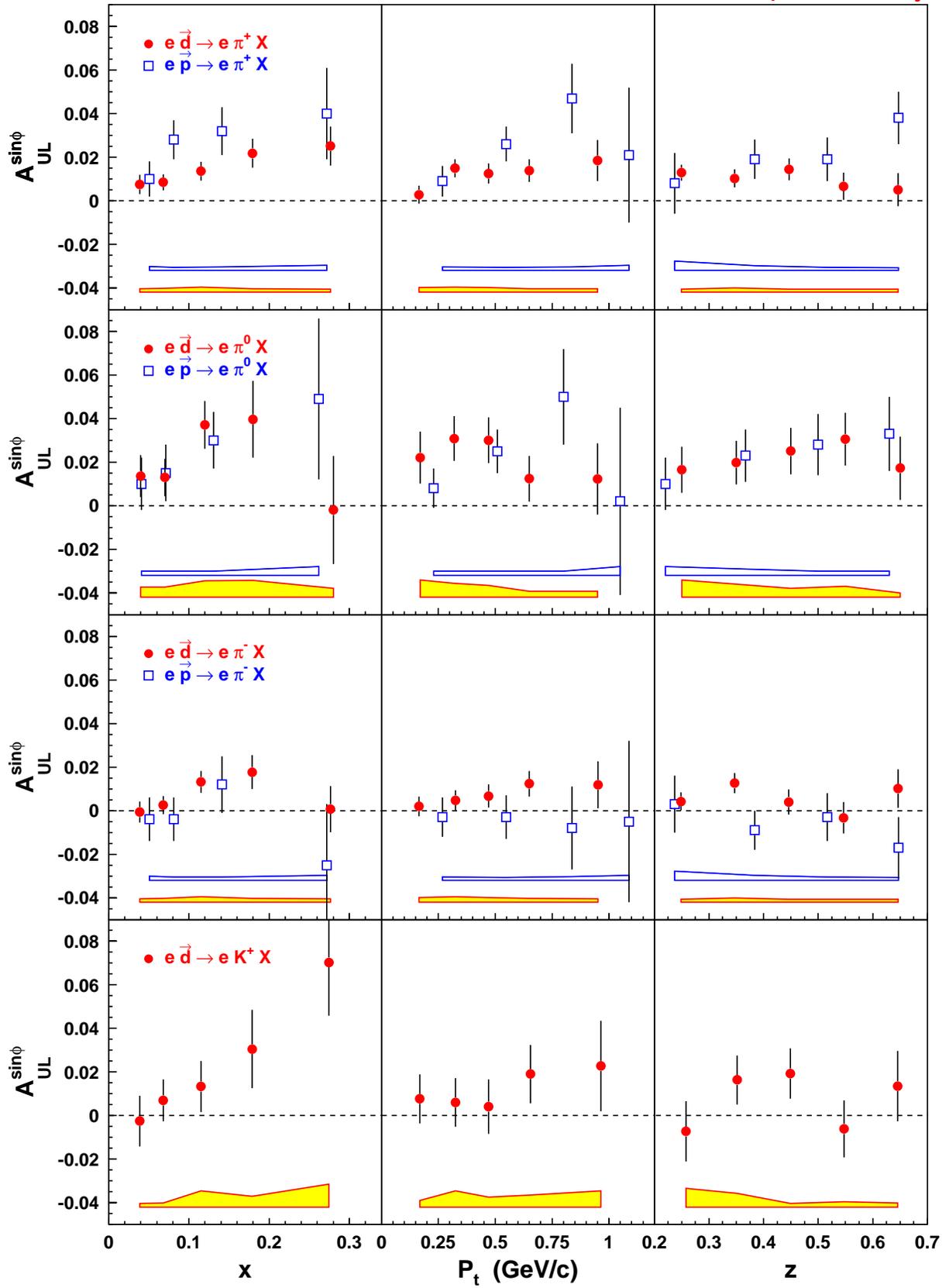
$$A_{\text{UL}}^{\text{W}} = \frac{\sum_{i=1}^{N^+} W(\phi_i^+) - \sum_{i=1}^{N^-} W(\phi_i^-)}{\frac{1}{2}[N^+ + N^-]} \Leftrightarrow A_{\text{UL}} = A_{\text{UL}}^{\text{W}} \cdot W(\phi)$$

$$W(\phi) = \sin \phi, \sin 2\phi, \dots$$

$$\begin{aligned} \left\langle \frac{P_{\text{T}}}{z M_{\text{h}}} \sin \phi \right\rangle_{\text{UL}} \propto (1-y) & \left[S_{\text{T}} \sum_{a, \bar{a}} (e_a^2 x h_1^a(x) H_1^{\perp a}(z)) \right. \\ & \left. + \frac{1}{Q} S_{\text{L}} \sum_{a, \bar{a}} (e_a^2 x h_{\text{L}}^a(x) H_1^{\perp a}(z)) \frac{2(2-y)}{\sqrt{1-y}} + \dots \right] \end{aligned}$$

HERMES: longitudinal polarised target: ($S_{\text{T}} \propto \sin \theta_{\gamma} \propto 1/Q$) first term contributes with 15% to 20%

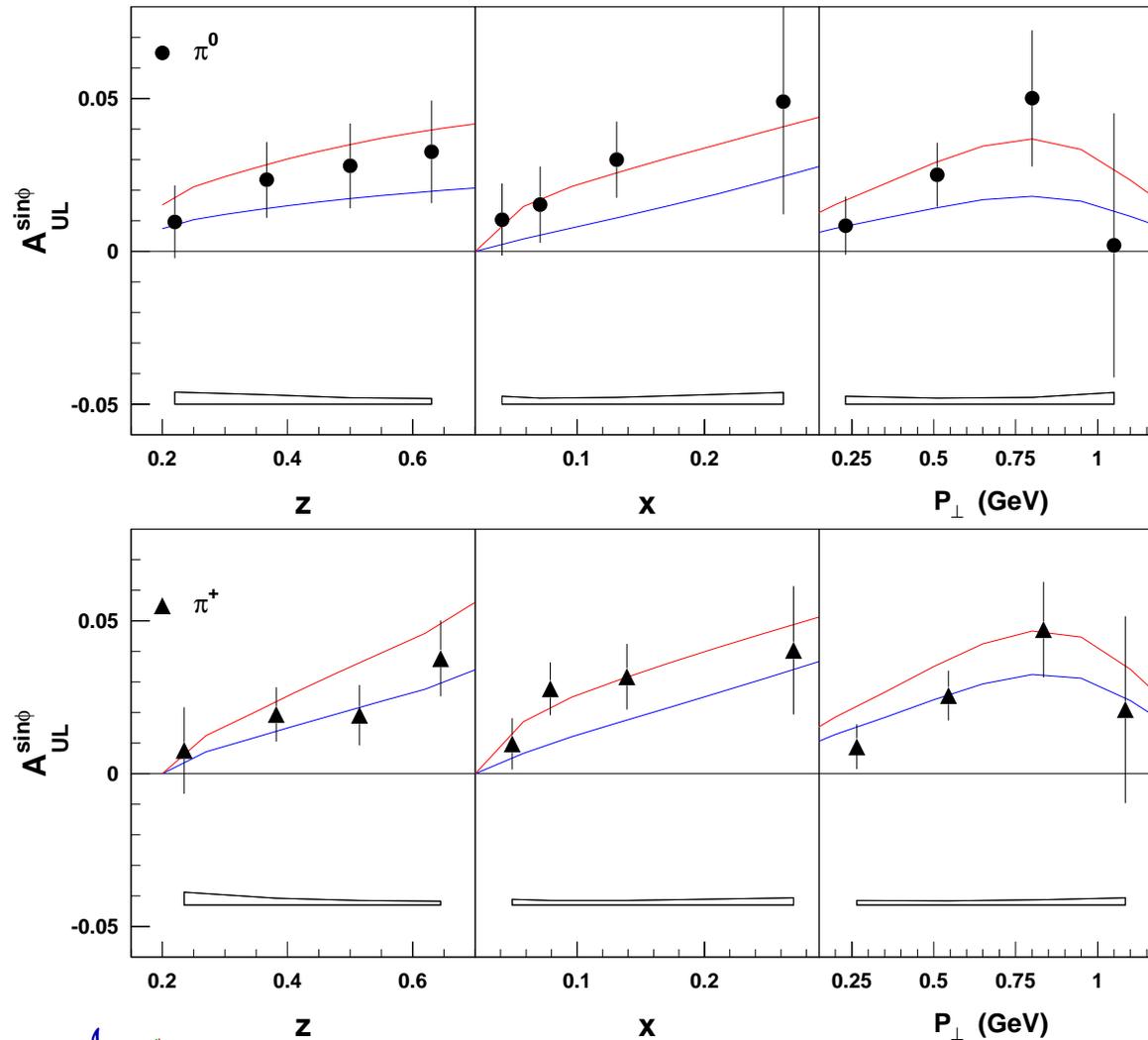
deuteron data is preliminary



model calculations for $A_{UL}^{\sin\phi}$

[Oganessyan et al., hep-ph/9808368, PLB 483 (2000) 69]

$e\vec{p} \rightarrow e \pi X$



approximation:

$$h_L(x) = h_1(x) - \frac{d}{dx} h_{1L}^{\perp(1)}(x) \approx h_1(x)$$

upper limit: $h_1 = (f_1 + g_1)/2$
Soffer inequality

lower limit: $h_1 = g_1$
non-relativistic limit

'Collins guess' for H_1^{\perp} :

$$A_C(z, k_T) = \frac{|k_T| H_1^{\perp}(z, k_T^2)}{M_h D_1(z, k_T^2)} = \eta \frac{M_C |k_T|}{M_C^2 + k_T^2}$$

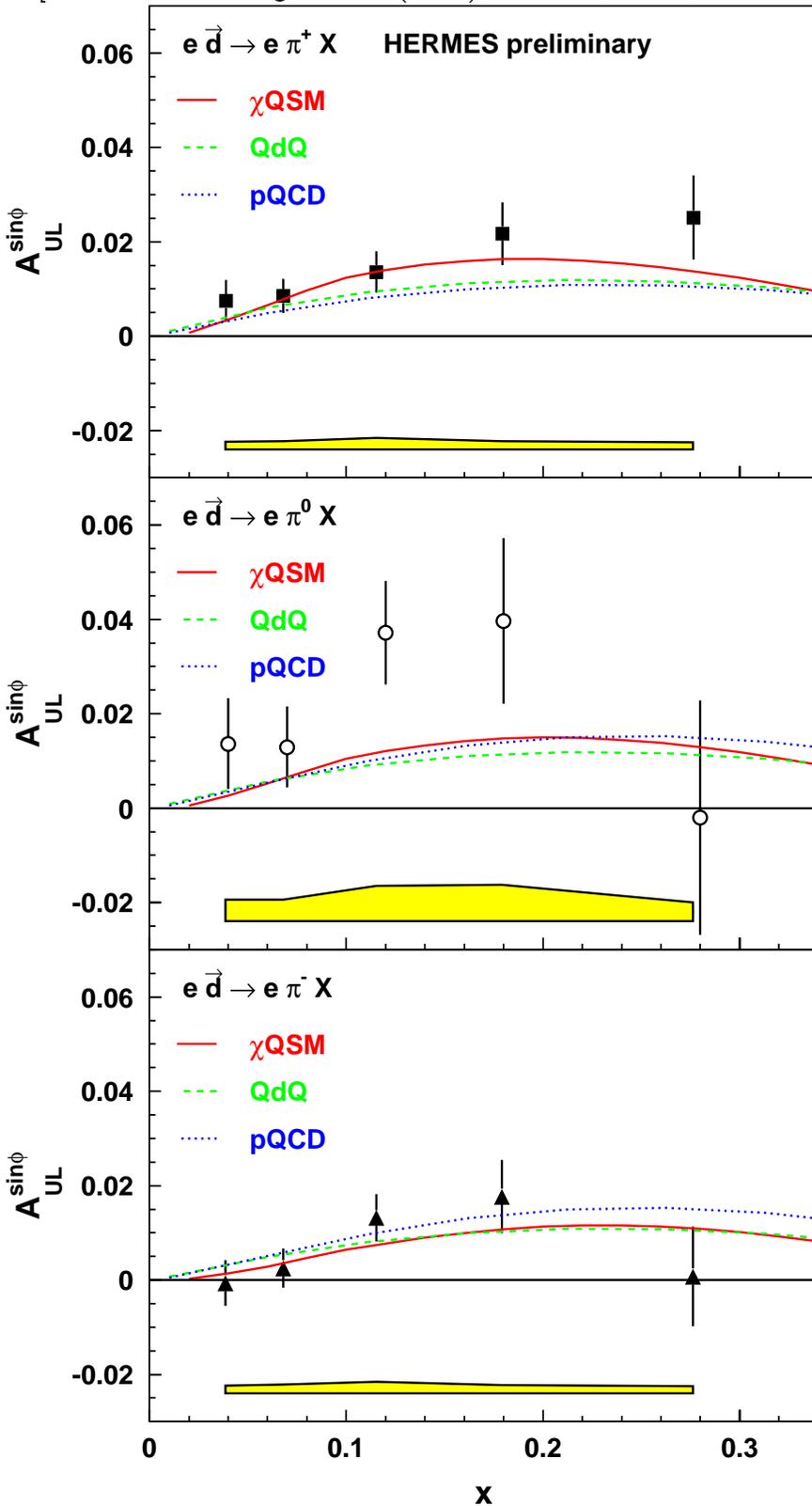


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SPIN02 @ BNL, NY (US), September 9-14, 2002

[Ma, Schmidt, Yang, PRD63(2001); Efremov, Goeke, Schweitzer, EPC24(2002)]



approximation:

$$h_1(x) :$$

$$h_L^a(x) = 2x \int_x^1 dx' \frac{h_1^a(x')}{x'^2} + \tilde{h}_L^a$$

$$\tilde{h}_L \simeq 0$$

$$H_1^\perp :$$

χ QCD:

$$\left| \frac{\langle H_1^\perp \rangle}{\langle D_1 \rangle} \right| = (12.5 \pm 1.4)\%$$

QdQ, pQCD:

'Collins guess'

model calculations for $A_{UL}^{\sin 2\phi}$

[Efremov, Goeke, Schweitzer, EPC24, 407 (2000)]

chiral quark-soliton model:

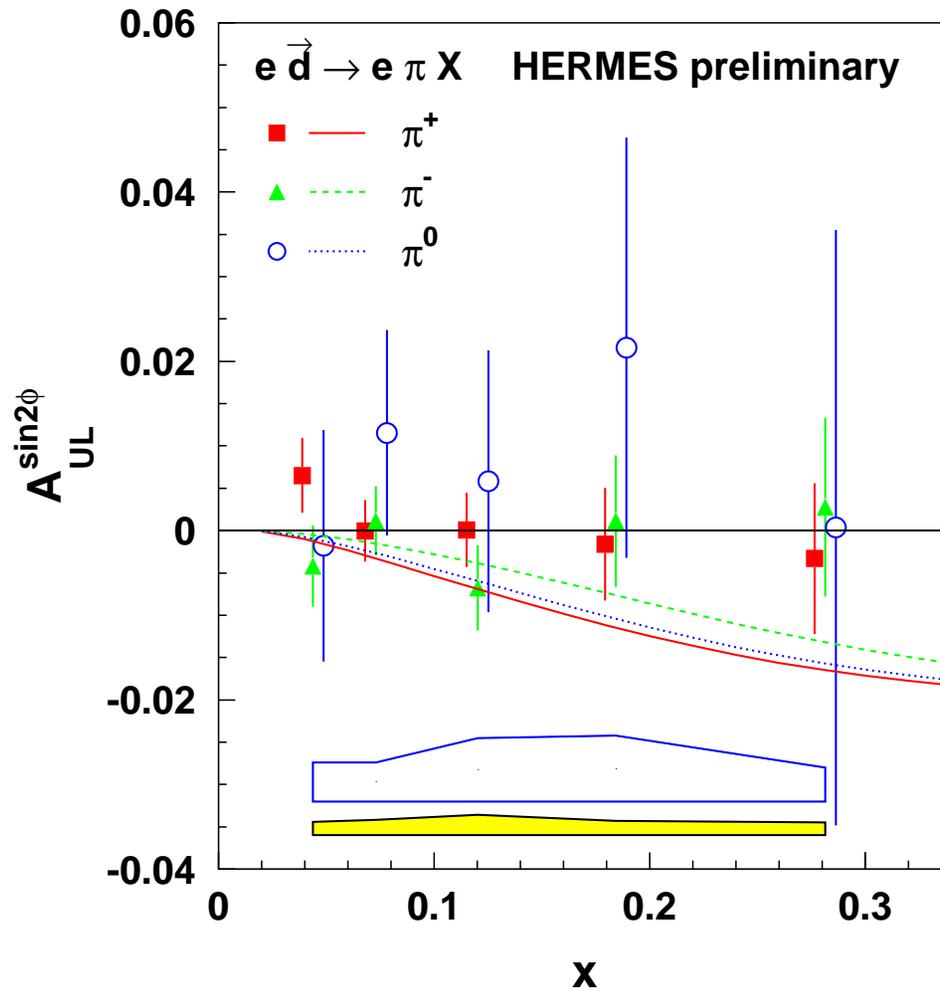
$$h_1(x) :$$

$$h_L^a(x) = 2x \int_x^1 dx' \frac{h_1^a(x')}{x'^2} + \tilde{h}_L^a$$

$$\tilde{h}_L^a \simeq 0$$

$$H_1^\perp :$$

$$\left| \frac{\langle H_1^\perp \rangle}{\langle D_1 \rangle} \right| = (12.5 \pm 1.4)\%$$



remarks on model calculations

$\sin \phi$ moments from proton + deuteron targets well described by various model calculations based on Collins effect ($\sim h_1 \otimes H_1^\perp$)

BUT

\Rightarrow @ longitudinally polarised target: S_T w.r.t. $\gamma^* \propto 1/Q$

$A_{LU}^{\sin \phi} \sim$ twist-3: $h_L H_1^{\perp(1)}$ contribution $\approx 75\%$ \leftarrow opposite sign
while $h_1 H_1^{\perp(1)}$ contribution $\approx 25\%$ \checkmark [K. Oganessyan], [Efremov, Goeke, Schweitzer]

\Rightarrow SSA from final state interaction (gluon exchange) \equiv Sivers effect $\sim f_{1T}^\perp \otimes D_1$
Collins + Sivers effect show different dependence on z

\Rightarrow for transversely polarised target:

$\sin(\phi_h^l + \phi_S^l) \sim h_1 \otimes H_1^\perp$ while $\sin(\phi_h^l - \phi_S^l) \sim f_{1T}^\perp \otimes D_1$

$$A_{LU}^{\sin \phi}$$

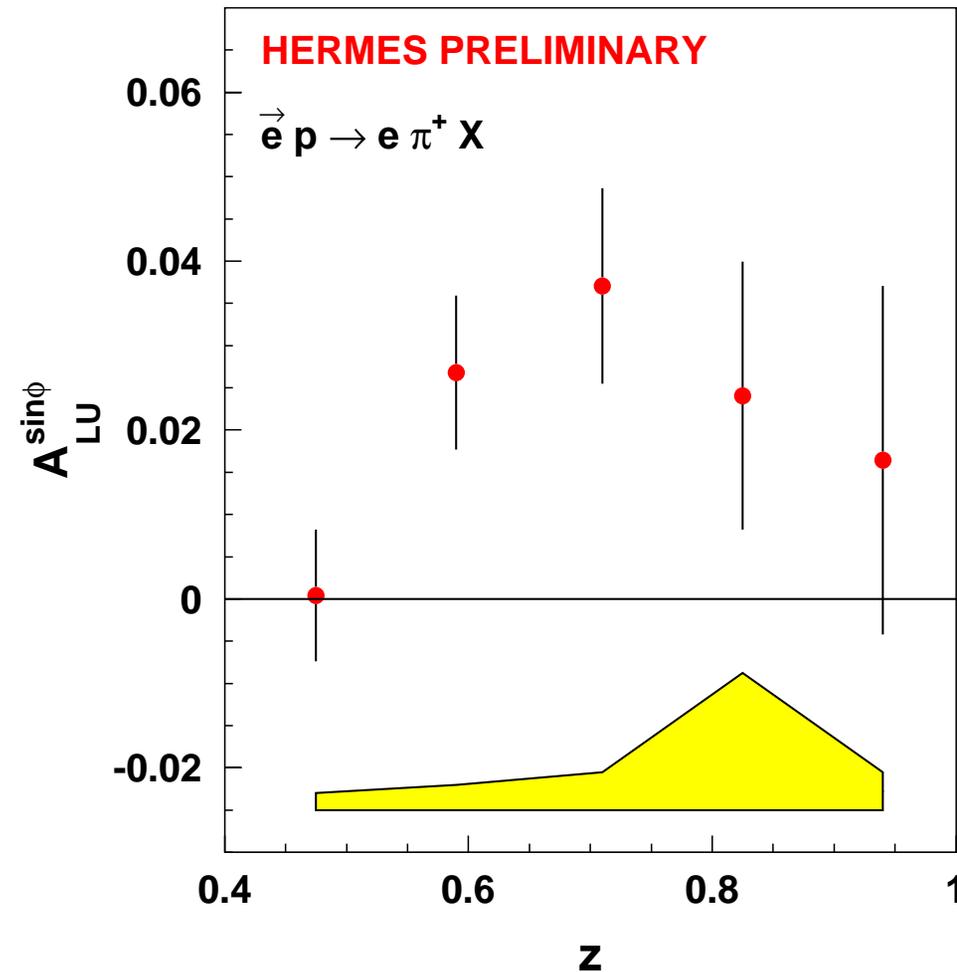
$$A_{LU}^{\sin \phi}$$

$$= \frac{\sum_{i=1}^{N^+} \sin(\phi_i^+) - \sum_{i=1}^{N^-} \sin(\phi_i^-)}{\frac{1}{2}[N^+ + N^-]}$$

$$\propto \frac{\sum_{a,\bar{a}} (e_a^2 x e^a(x) H_1^{\perp a}(z))}{\sum_{a,\bar{a}} (e_a^2 x f^a(x) D_1^a(z))}$$

$e^a(x)$... twist-3 chiral odd DF

$H_1^{\perp a}(z)$... Collins FF



summary & outlook

single-target + single-beam spin azimuthal asymmetries measured in $\pi(K)$ electroproduction with longitudinally polarised target and beam

$A_{UL}^{\sin\phi}$ well described by model calculations based on **Collins effect**

⇒ non-ambiguous measurement of **transversity** will be possible with transversely polarised target:

→ **HERMES run-II 2002++**

